

## **Title of the Invention**

Lens Turret with Back Focal Length Adjustment

## **Background of the Invention**

### **1. Field of the Invention**

5 The present invention relates to an optical apparatus that has a plurality of lenses and is used for digital still cameras. In the optical apparatus, by providing additionally a kind of optical element made of glass, plastic or the like that has a higher refractive index than that of air and by inserting said element between the rearmost element of lens and the image sensor the back focal length of the lens  
10 with shorter back focal length can be extended without changing its focal length itself.

### **2. Background Art**

A lens turret is popularly used to obtain multiple focal lengths in a camera. However, in the case of digital still cameras (hereinafter referred to as DSC) or  
15 especially in the case of mobile phone DSC, lens modules are required to be extremely small due to the limited space for the lens module. Conventional lens turrets usually have two or three lenses of different focal lengths, and the lenses are fixed on a disk surrounding an axis, and the disk is rotatable around the axis so that one of the lenses can be set at the picture taking position. In the  
20 conventional lens turrets, the lenses are simply fixed on the disk, so the heights of lenses are all different. The lens with longer focal length is much higher than the

lens with shorter focal length. Fig. 1 shows how different the heights of two lenses are as a common example. Moreover, if the lenses are positioned closely each other surrounding the axis, the lens barrel of longer focal length lens (hereinafter referred to as a telephoto lens) cuts in and disturb the light path of the shorter focal length lens (hereinafter referred to as a wide-angle lens) as shown by Fig. 2, because both of the lenses are placed at the same level on the disk. Consequently, there is a limit for shortening the distance between the lens positions, and that makes it difficult for the total size of lens turret to be compact. If the lenses are so positioned as not to disturb their light paths with each other, they should be positioned as shown in Fig. 3, and the distance between the two lenses should be much longer than the distance of the case shown in Fig. 2.

It is therefore an object of this invention to provide a lens turret that is much smaller area-wise, and much lower and flat height-wise.

### **Summary of the Invention**

A primary object of the present invention is to provide a lens turret that is extremely compact and flat in size and suitable for digital still cameras and mobile phone digital cameras comprising a lens turret rotatable around an axis and having plurality of lenses mounted thereon, a driving mechanism to rotate the lens turret so that one of the lenses can be set at the picture taking position, and a means to adjust and extend the back focal length of the wide-angle lens shaped like a column or square column and made of glass, plastic or the like that has higher refraction index than that of air

Lenses are designed having a back focal length, which is the distance between the rearmost lens element and the focal plane of image sensor. This distance is fixed

when the design was finalized. Usually when designing lenses, the designer considers the space between the rearmost element and the image sensor being filled by air, and uses the refractive index of air for his design calculation. It is a well-known fact that if an additional optical element that has a higher refractive index than that of air is inserted between the rearmost element and the image sensor, the back focal length of the lens is extended to some extent, and yet the focal length itself is not changed at all.

By making use of this phenomenon of back focal length extension, and by inserting an additional optical element between the lens and image sensor, the lens can be placed farther apart from the image sensor than its original position.

By using an additional element made of a material with a higher refractive index than the refractive index of air being placed between the lens and the image sensor, the present invention enables the lens turret to have the wide-angle lens placed higher in position than its original position so that the wide-angle lens can be placed almost at the same level as the telephoto lens, and when they are built in a DSC, the telephoto lens does not protrude and at the same time the distance between the both lenses can be closer preventing the telephoto lens barrel from disturbing the light path of the wide-angle lens so that the total size of the lens turret can be much more compact.

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### **Brief Description of the Drawings**

Fig. 1 is a perspective view of a camera with a conventional lens turret;

Fig. 2 is a partly cross-sectional view of the lens turret system in which both the wide-angle and telephoto lenses are too closely positioned each other and a part of

light path of the wide-angle lens is cut and disturbed by a part of telephoto lens barrel;

Fig. 3 is a partly cross-sectional view of the lens turret system in which both the wide-angle and telephoto lenses are positioned spaciously enough with each other  
5 so that any part of the light path of wide-angle lens may not be cut and disturbed by a part of telephoto lens barrel;

Fig. 4 is an example design of a wide-angle lens to be used for the lens turret;

Fig. 5 is a modified design of the lens design of Fig. 4 using an additional element to adjust and extend the back focal length;

10 Fig. 6 is a partly cross-sectional view of the lens turret system in which both the wide-angle and telephoto lenses are very closely positioned each other using an additional element of back focal adjustment, and yet any part of light path of the wide-angle lens is not cut and disturbed by a part of telephoto lens barrel;

Fig. 7 is a perspective view of the lens turret of the first embodiment of the present  
15 invention in which the wide-angle lens is in the picture taking position;

Fig. 8 is a perspective view of the lens turret of the first embodiment of the present invention in which the telephoto lens is in the picture taking position; and

Fig. 9 is a perspective view of the lens turret of the second embodiment of the present invention in which the wide-angle lens is in the picture taking position.

### Detailed Description of the Invention

As described hereinbefore, the back focal length can be extended by inserting an additional element which is made of a glass, plastic or the like that has a higher refractive index than that of air. And the extension can be calculated using  
5 formulas as follows.

Thickness of the additional element = T

Refractive index of the additional element = RI

Original Back focal length = BFL1

Extended distance = ED

10 Extended back focal length = BFL2

$$T - T/RI = ED$$

and

$$BFL + ED = BFL2$$

Using a sample design of a wide-angle lens as shown in Fig. 4, of which  
15 specifications are as follows, and an additional element of 1.5 mm thick made of optical glass with a refractive index of 1.52, if the back focal length adjustment is calculated, the result of calculation is as follows.

Lens specifications:

$$Fno = 4.06$$

20 Focal length = 2.15 mm

$$\text{Back focal length} = 1.44 \text{ mm}$$

Element = 2 plastic aspherical elements

$$ED = 1.5 - 1.5/1.52 = 0.513$$

and

$$BFL2 = 1.44 (BFL1) + 0.513 = 1.953$$

As calculated above, for the original back focal length of 1.44 mm, about 35.6%  
5 of extension can be obtained and the extended back focal length is 1.953 mm.  
Thus by inserting the additional element (4 shown in Fig. 5), the lens can be  
placed farther apart from the image sensor by 0.513 mm. As the result of this  
back focal length extension, the lens design can be changed from the design in Fig.  
4 to the design in Fig. 5. In both the designs, the focal lengths of 2.15 mm are  
10 exactly the same and unchanged.

Fig. 3 shows the relative positions of the wide-angle lens (1) and the telephoto  
lens (2) when those lenses are positioned on the lens turret not to disturb the light  
path of each lens with each other without the additional element (4) to extend the  
back focal length of the wide-angle lens (1). Fig. 2 shows the status of both  
15 lenses which are positioned as close as possible without the additional element (4)  
to extend the back focal length and without considering that the lens barrel (3) of  
the telephoto lens (2) cuts a part of light path of wide-angle lens (1). Fig. 6  
shows the status of the both lenses when the additional element (4) to extend the  
back focal length of the wide-angle lens (1) is inserted between the rearmost  
20 element (5) of the wide-angle lens (1) and the image sensor (6), and also shows  
the status that as the result of the inserting the additional element (4) the back  
focal length of the wide-angle lens (1) is extended and the wide-angle lens (1) is  
moved upward (forward) and yet the distance (7) between the both lenses can be  
the same as the distance (7) shown in Fig. 3. As shown in Fig. 6, now any part of  
25 the light path of the wide-angle lens (1) is not disturbed by any part of the

telephoto lens (2).

Figs. 7 and Fig. 8 show a preferable embodiment of the present invention, namely the lens turret with back focal length adjustment, which comprises a wide-angle lens (1), a telephoto lens (2), a lens turret disk (8) rotatable around an axis (9) and  
5 having the lenses mounted thereon, an additional element (4) to adjust and extend the back focal length of the wide-angle lens (1), gear teeth (10) provided on the rim of the lens turret disk (8), a housing (11) in which all the wide-angle lens (1), the telephoto lens (2), the image sensor (6) and the lens turret disk (8) are assembled and a rack (12).

10 Since the means of back focal length adjustment, the additional element (4), is provided with the wide-angle lens (1) between the rearmost lens element of the wide-angle lens (1) and the image sensor (6), the wide-angle lens (1) is positioned almost at the same level as the telephoto lens (2) as shown in Fig. 6. The lens turret disk (8) is rotatable around the axis (9), and on the rim of the lens turret disk  
15 (8) the gear teeth (10) are provided and they are engaged with the teeth of the rack (12). The two lenses are moved by rotation of the lens turret disk (8) so that one of them comes to the picture taking (image capturing) position. When the rack (12) is moved manually sliding from side to side, the lens turret disk (8) rotates and moves the lenses, and one of the lenses stops at a picture taking position  
20 above the image sensor (6) with a click stop. If the rack (12) is moved in a reverse direction the other lens comes to the picture taking position. Thus by using the means of back focal length adjustment, namely the additional element (4) made of glass, plastic or the like that has a higher refractive index than the refractive index of air and by keeping the additional element (4) just underneath  
25 the rearmost element (5) of the wide-angle lens (1) between the rearmost element

(5) and the image sensor (6), the wide-angle lens (1) can be placed farther upward (forward) apart from the image sensor (6) so that the both lenses can be positioned almost at the same level and the distance (7) shown in Fig. 6 between the both lenses can be minimized. Consequently the total size of the lens turret can be as compact as possible.

Fig. 10 shows another preferable embodiment of the present invention, namely the lens turret with back focal length adjustment, which comprises a wide-angle lens (1), a telephoto lens (2), a lens turret disk (8) rotatable around an axis (9) and having the lenses mounted thereon, an additional element (4) to adjust and extend the back focal length of the wide-angle lens (1), gear teeth (10) provided on the rim of the lens turret disk (8), a housing (11) in which all the wide-angle lens (1), the telephoto lens (2), the image sensor (6) and the lens turret disk (8) are assembled, and a DC motor (13) with a worm screw (14) fixed with the motor shaft.

Since the means of back focal length adjustment, the additional element (4), is provided with the wide-angle lens (1) between the rearmost lens element of the wide-angle lens (1) and the image sensor (6), the wide-angle lens (1) is positioned almost at the same level as the telephoto lens (2) as shown in Fig. 6. The lens turret disk (8) is rotatable around the axis (9), and on the rim of the lens turret disk (8) the gear teeth (10) are provided, they are engaged with the worm screw (14) fixed with the motor shaft. The two lenses are moved by rotation of the lens turret disk (8) so that one of them comes to the picture taking (image capturing) position. When the DC motor (13) rotates, the worm screw (14) rotates and the lens turret disk (8) rotates and moves the lenses, and one of the lenses stops at a picture taking position above the image sensor (6) with a stopper. If the motor



(13) rotates in a reverse direction the other lens comes to the picture taking position. Thus by using the means of back focal length adjustment, namely the additional element (4) made of glass, plastic or the like that has a higher refractive index than the refractive index of air and by keeping the additional element (4) just underneath the rearmost element (5) of the wide-angle lens (1) between the rearmost element (5) and the image sensor (6), the wide-angle lens (1) can be placed farther upward (forward) apart from the image sensor (6) so that the both lenses can be positioned almost at the same level and the distance (7) shown in Fig. 6 between the both lenses can be minimized. Consequently the total size of the lens turret can be as compact as possible.